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Software Cost Estimation and Sizing Methods: Issues and Guidelines

Shari Lawrence Pfleeger

RAND Corporation

February 16, 2005

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MONITOR: Jay Jordan, AFCAA Technical Director

INITIATED: January 1998

Part of RAND Project AIR FORCE, a Federally Funded Research and Development Center (FFRDC)

- Natalie Crawford, Vice President and Director of PAF
- Bob Roll, Director of Resource Management Program

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Overview

- What's the problem?
  - "It's tough to make predictions, especially about the future." --Yogi Berra
  - Do we need yet another cost estimation model?
- Issues
  - Uncertainty
  - Risk
- Results of RAND study:
  - Size estimation checklist
  - Cost estimation checklist
- Next steps?

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Related RAND Work

- ***An Overview of Acquisition Reform Cost Savings Estimates*, Mark Lorell and John C. Graser, MR-1329-AF**
- ***Military Airframe Acquisition Costs: The Effects of Lean Manufacturing*, Cynthia Cook and John C. Graser, MR-1325-AF,**
- ***Military Airframe Costs: The Effects of Advanced Materials and Manufacturing Processes*, Obaid Younossi, Michael Kennedy, and John C. Graser, MR-1370-AF**
- ***Military Jet Engine Acquisition: Technology Basics and Cost-Estimating Methodology*, Obaid Younossi, Mark V. Arena, Richard M. Moore, Mark Lorell, Joanna Mason, and John C. Graser, MR-1596-AF**
- ***Test and Evaluation Trends and Costs for Aircraft and Guided Weapons*, Bernard Fox, Michael Boito, John C. Graser, and Obaid Younossi, MG-109-AF**
- **http://www.rand.org/paf for more information**

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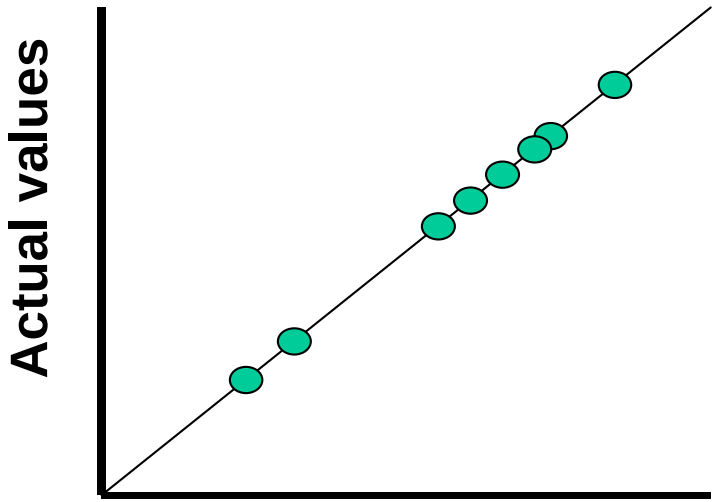
Variability and Uncertainty Are Facts of Life



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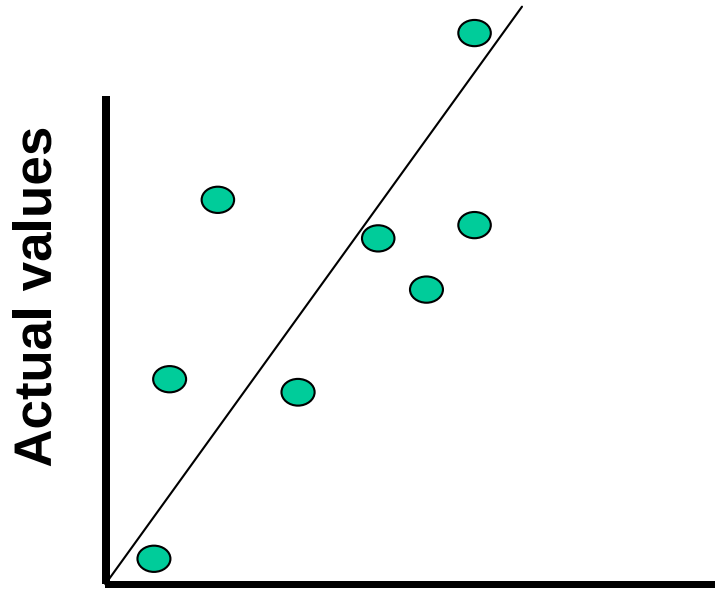

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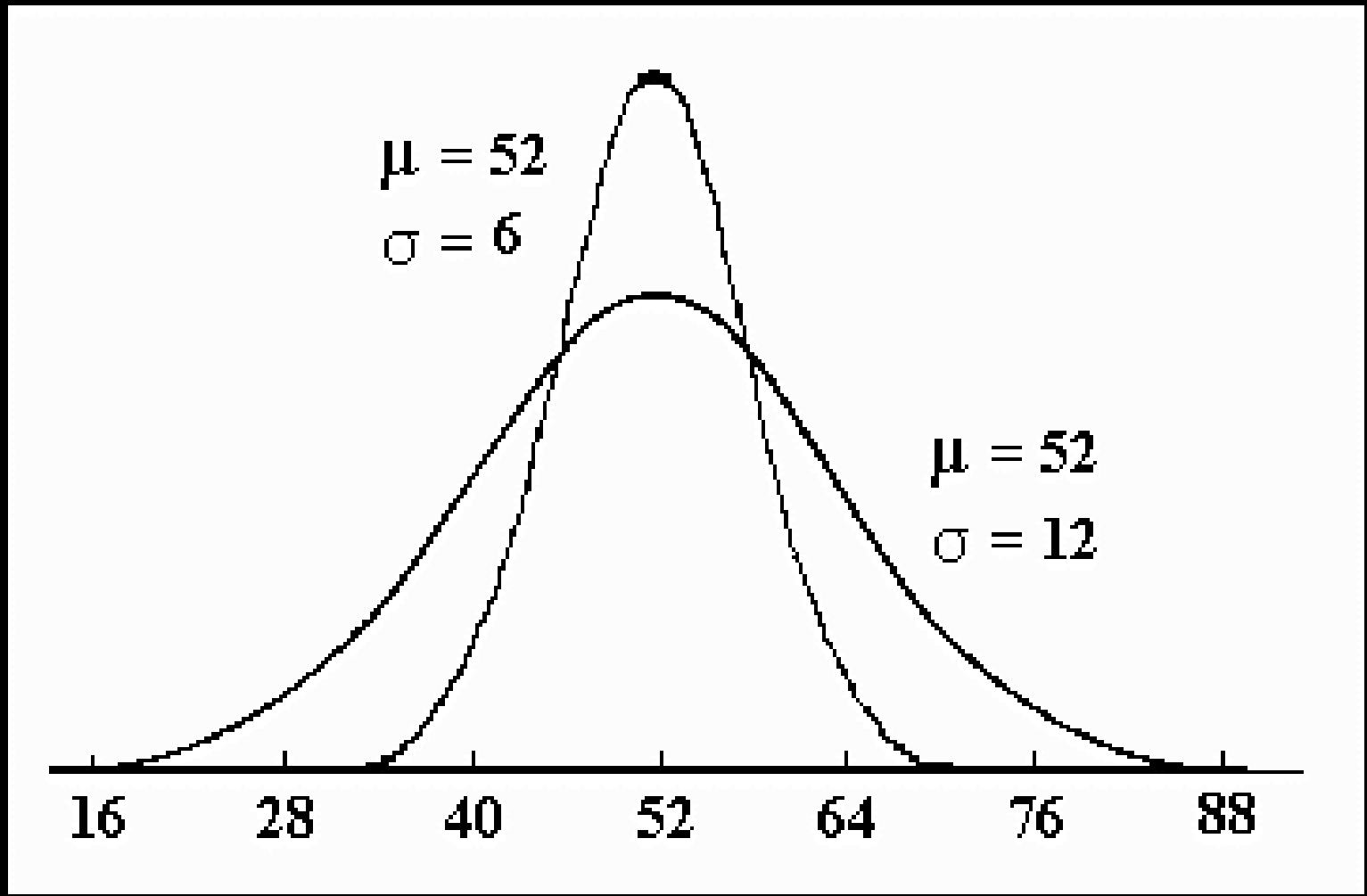
Reducing the Uncertainty



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Objectives

- Analyze the factors that influence the accuracy of an estimate.
  - Identify uncertainty
  - Determine how to reduce variability
- Focus on two things:
  - The decisions made during the estimation process (such as which methods and models to use)
  - The nature of the data used in estimation (such as software size)
- Improve accountability of risk in estimation process: Where can risk mitigation reduce the likelihood of variability?

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Methodology

- Understand the nature of risk in software cost estimation
  - Taxonomy of risk, uncertainty, error, accuracy
- Sources of risk and error
  - Basic model of error insertion: select method, collect data, apply method
- Options in developing estimates
  - Focus on sizing and on choice of estimation technique
- Strategies to mitigate the risks
  - Checklists to provide framework for decision-making

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Definitions

- **Risk**: a problem waiting to happen. Usually associated with a confidence level: "I am 95% sure that the number will be between X and Y."
- **Uncertainty**: the degree to which we are unsure that something will occur
- **Error**: the degree to which the estimated value is different from the actual value
- **Variability**: the range of possible values for a data element
- Therefore, **accuracy** involves not only the amount of error but also the appropriate variability in the estimate

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Are We On the Right Track?

- **Memorandum of 13 June 2004 from Undersecretary of the Air Force: "Revitalizing the Software Aspects of Systems Engineering"**
- **Number 1 (of 10) recommendation: High Confidence Estimates**
  - **"Estimate the software development and integration effort (staff hours), cost and schedule at high (80-90%) confidence."**
- **Number 2 recommendation: Realistic Program Baselines**
  - **"Ensure cost, schedule and performance baselines are realistic and compatible. … The program budget must support the high confidence estimates for effort (staff hours), cost, and schedule."**
- **Number 3 recommendation: Risk Management**
  - **"Continuously identify and manage risks specific to computer systems and software as an integral part of the program risk management process. Ensure the risks, impact, and mitigation plans are appropriately addressed during program and portfolio reviews."**

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Key Issues

- **Dependence on context, expertise, experience, intention of model**
- **Role of software size**
- **Control over risk factors**
- **Pros and cons of each sizing or estimation method**

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Results: Sizing

- **Survey of sizing methods**
  - ✓ **Source**
  - ✓ **References**
  - ✓ **How the method works**
  - ✓ **When to use it, when not to use it**
- **Risk checklist for sizing methods**
  - ✓ **Symptoms or warning signs**
  - ✓ **Mitigation strategies**
- **Reorganized risk checklist for sizing**
  - ✓ **Questions**
  - ✓ **Suggested actions**

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Many Ways to Estimate Size (1 of 2)

- **Source lines of code (SLOC):** a method that estimates the total number of lines of code in the finished software project
- **Function points and feature points:** methods that measure the amount of functionality in a system by counting and weighting inputs, outputs, queries, and logical and interface files
- **Object points:** a method that measures size by high-effort items, such as server data tables, client data tables, and screens and reports reused from previous projects
- **Application points:** a method building on object points, adding rating scales of a project's productivity

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Many Ways to Estimate Size (2 of 2)

- **Predictive object points:** a method also building on object points, adding information about how objects are grouped into classes
- **Analogies:** a method using other, completed projects with similar characteristics to the proposed project to suggest the likely size
- **Unified Modeling Language (UML) constructs:** a relatively new method based on use cases, a technique for describing how users will interact with the system to perform functions

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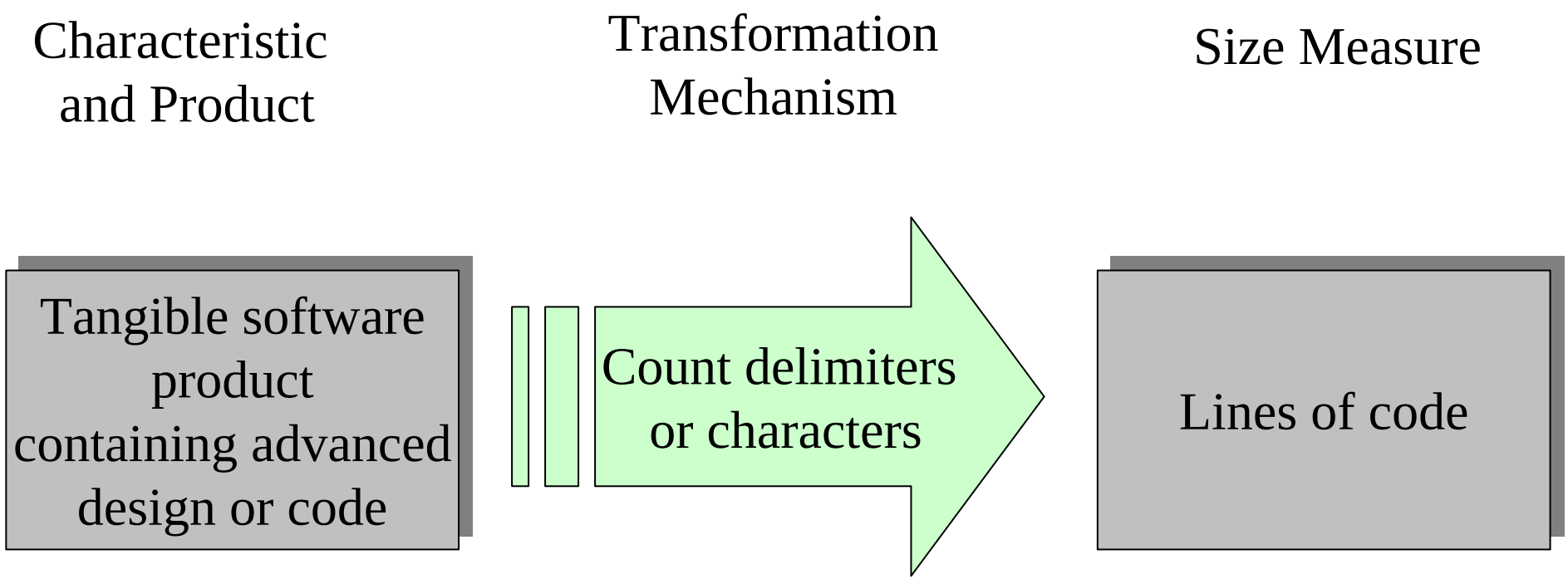
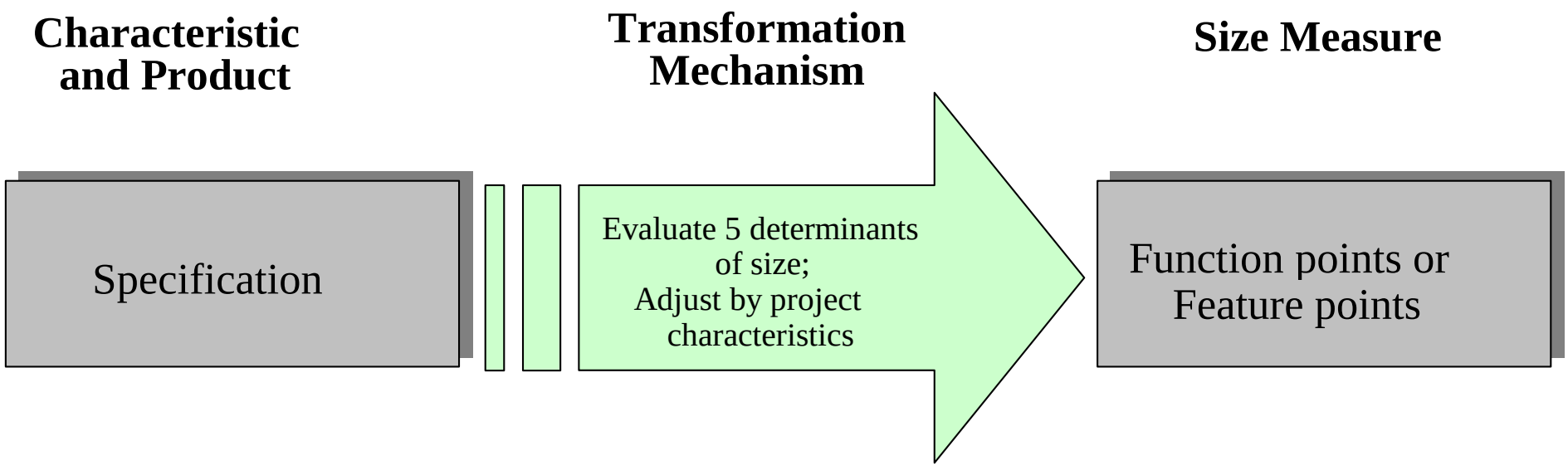
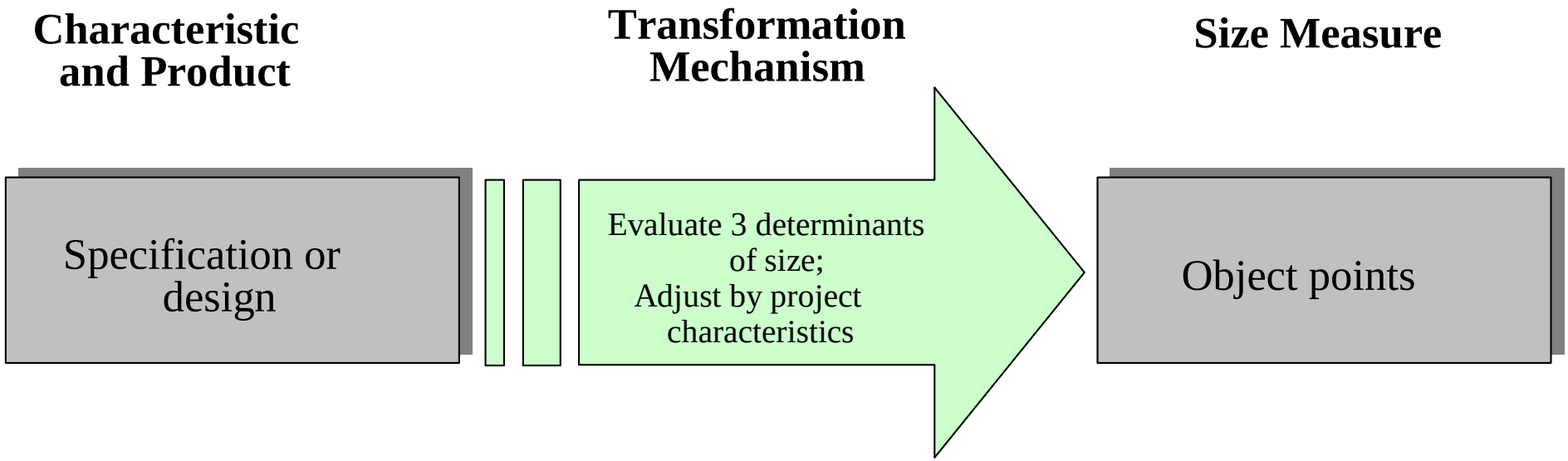
Size Estimation Using "Tangible" Product



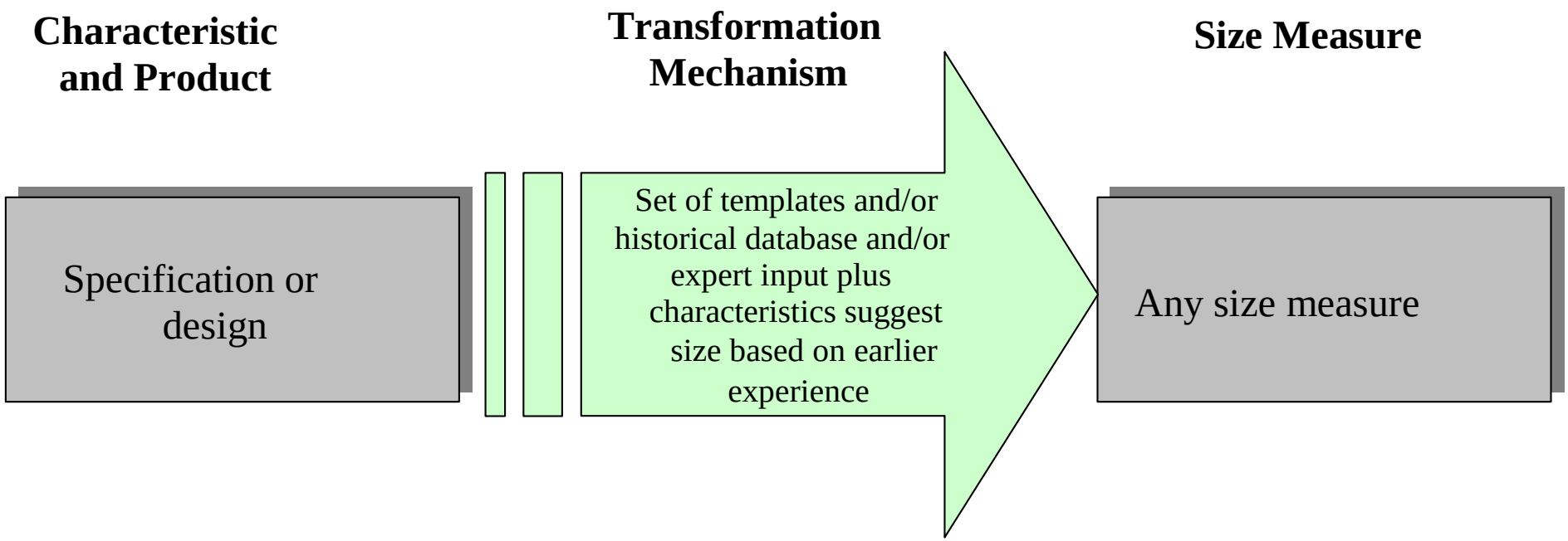
Size Estimation Using Function Points



Size Estimation Using Object Points



Size Estimation Using Analogies and Expert Judgment



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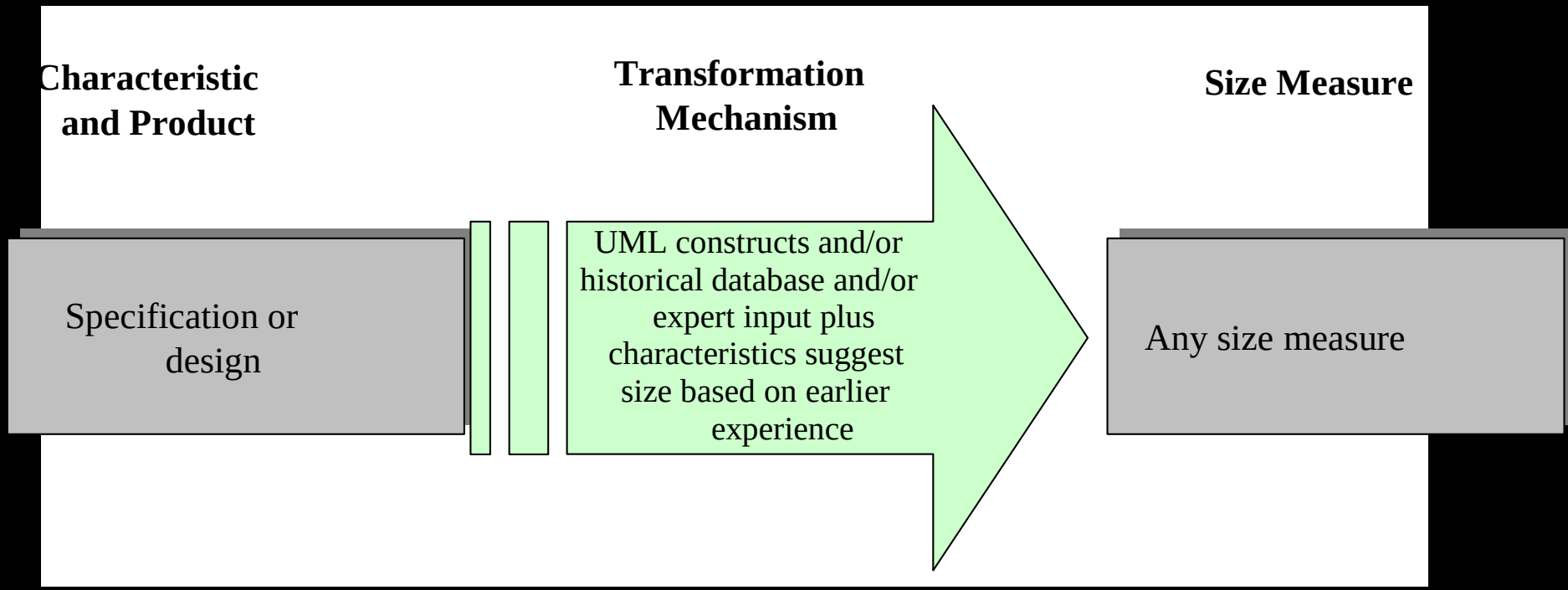
Size Estimation Using Use Cases



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Example: Survey of Sizing Methods Function Points and Feature Points

Source:

- Albrecht, Allan J. "Measuring application development," *Proceedings of the IBM Applications Development Joint SHARE/GUIDE Symposium*, Monterey, California, 1979, pp. 83-92.

References:

- An automated function point calculator available at http://www.engin.umd.umich.edu/CIS/course.des/cis525/js/f00/artan/functionpoints.htm
- *International Function Point User's Group* information about certifying counters, using the method, and more, are available at http://www.ifpug.org
- International Function Point Users Group, *Function Point Counting Practices Manual*, Release 4.1.1, 2001.
- International Function Point Users Group, *Guidelines to Software Measurement*, Release 1.1, 2001.
- A mapping from function points to lines of code is discussed in A.J. Albrecht and J.E. Gaffney, "Software Function, Source Lines of Code, and Development Effort Prediction," *IEEE Transactions on Software Engineering,* Vol. SE-9, No. 6, November 1983, pp. 639 – 647.

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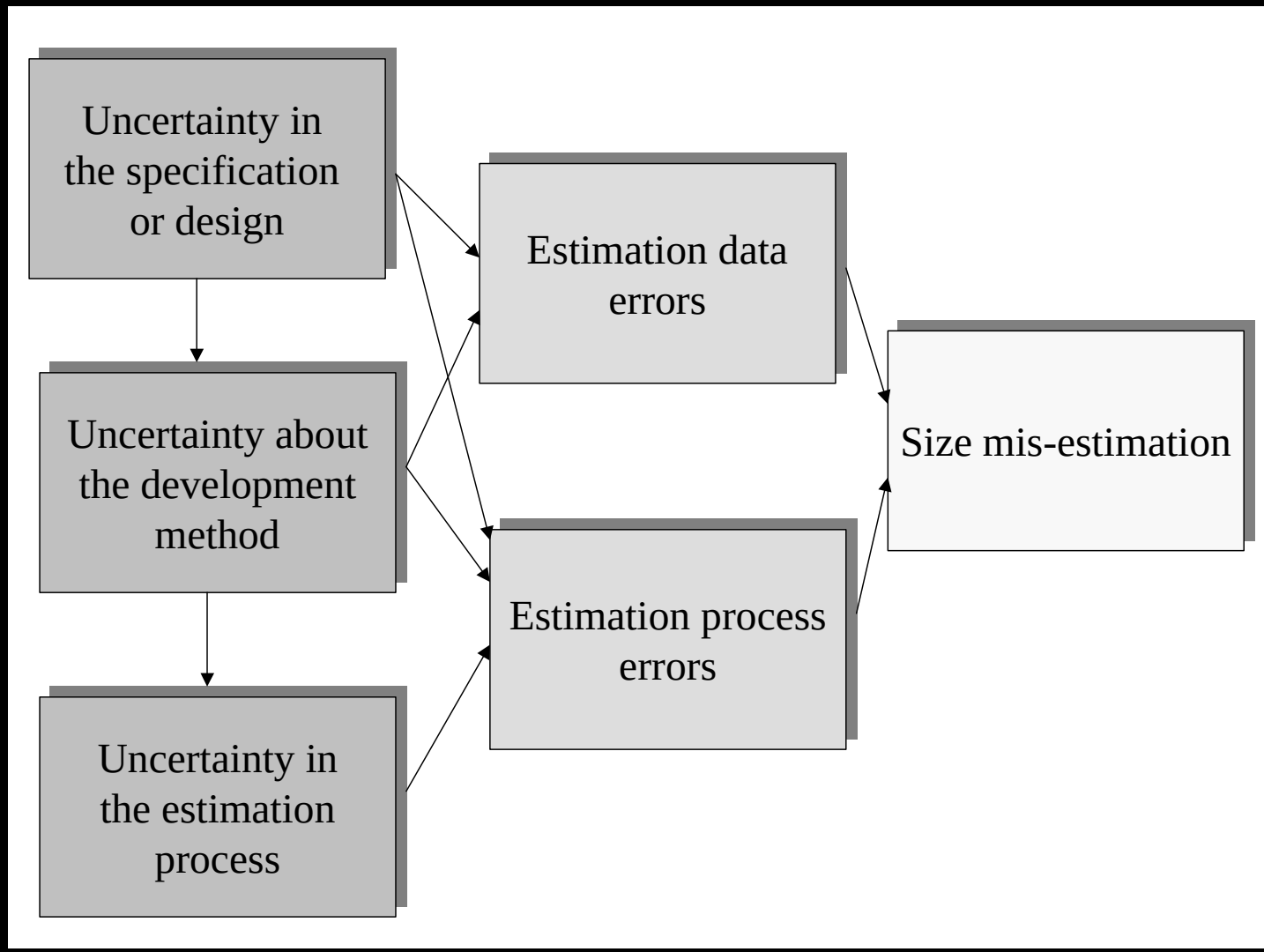
What Causes Errors in Size Estimation?



Issues to Consider

- Counting physical objects
  - May not be available
- Counting notional constructs
  - Difficult relating to non-tangible items
- Using historical data
  - Lack of empirical evidence for new systems or approaches
- Using analogies
  - May not be appropriate or scalable
- Tracking changes and progress over time
  - May conflict with intent of size estimation model
- Calibration
  - Requires bank of historical data

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Risk: *Problems in understanding the requirements or design* *(1 of 2)*

- Symptoms or warning signs: Especially when a system is groundbreaking, the organization commissioning the system may not know how to describe what it wants. Warning signs of uncertainty associated with the specification or design include repeated revision of the specification or design documents, the use of TBD or TBS (to be determined or supplied) throughout the documents, and incompleteness in important portions of the documents. Other symptoms of significant problems are ambiguity or conflict in the documents, or difficulty translating the requirements into design components or test plans.

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Risk: *Problems in understanding the requirements or design* *(2 of 2)*

- Mitigation strategies: The uncertainty in the requirements and design can be reduced by
  - holding requirements and design reviews,
  - by prototyping the requirements and design, and
  - by asking the test team to begin designing tests at the same time that designers are fleshing out detailed design from the requirements.

These activities force the developers to ask detailed, careful questions about the meaning and implication of each requirement or design component; then, problems surface early and are resolved well before implementation begins. A side benefit is that the requirements and design are of higher quality and lower uncertainty for estimation purposes.

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Example from Size Estimation Risk Checklist
(1 of 2)

Question: **Is the sizing method appropriate, given the intended use of the size estimate?**

Action: **Consider the following questions:**

- **Will the estimate be used to support a new cost/size estimate?**
- **Will it update an existing estimate?**
- **Will it be used to update progress or productivity?**
- **Will it be used to identify cost drivers?**
- **Will it be used to conduct a trade-off analysis?**

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Example from Size Estimation Risk Checklist
(2 of 2)

Question: **Is the sizing method appropriate, given the intended use of the size estimate?**

Action: **Using answers, determine if there is a match between intended use and appropriateness of information and method. Review "When to Use a Sizing Method" and "Tracking Changes and Progress Over Time."**

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Results: Estimation

- **Estimation survey**
  - ✓ **How it works**
  - ✓ **Advantages/disadvantages**
  - ✓ **Usage**
- **Estimation risk checklist**
  - ✓ **Sources of risk**
  - ✓ **Uncertainties and indicators of risk**
  - ✓ **Steps to take to address risk**

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Estimation Techniques Considered

- **Top-down**
- **Bottom-up/Work Breakdown Structure**
- **Analogies**
- **Expert Judgment**
- **Parametric/Algorithmic**

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Uses of Cost Estimates

Decisions about

- **Affordability**
  - **Development, training, repair, upgrades**
- **Investment**
  - **Capability provided, given time and resources**
- **Value**
  - **Can other options provide same capability for smaller cost, or more capability for same cost?**

Audience: Buyers, developers, users, researchers

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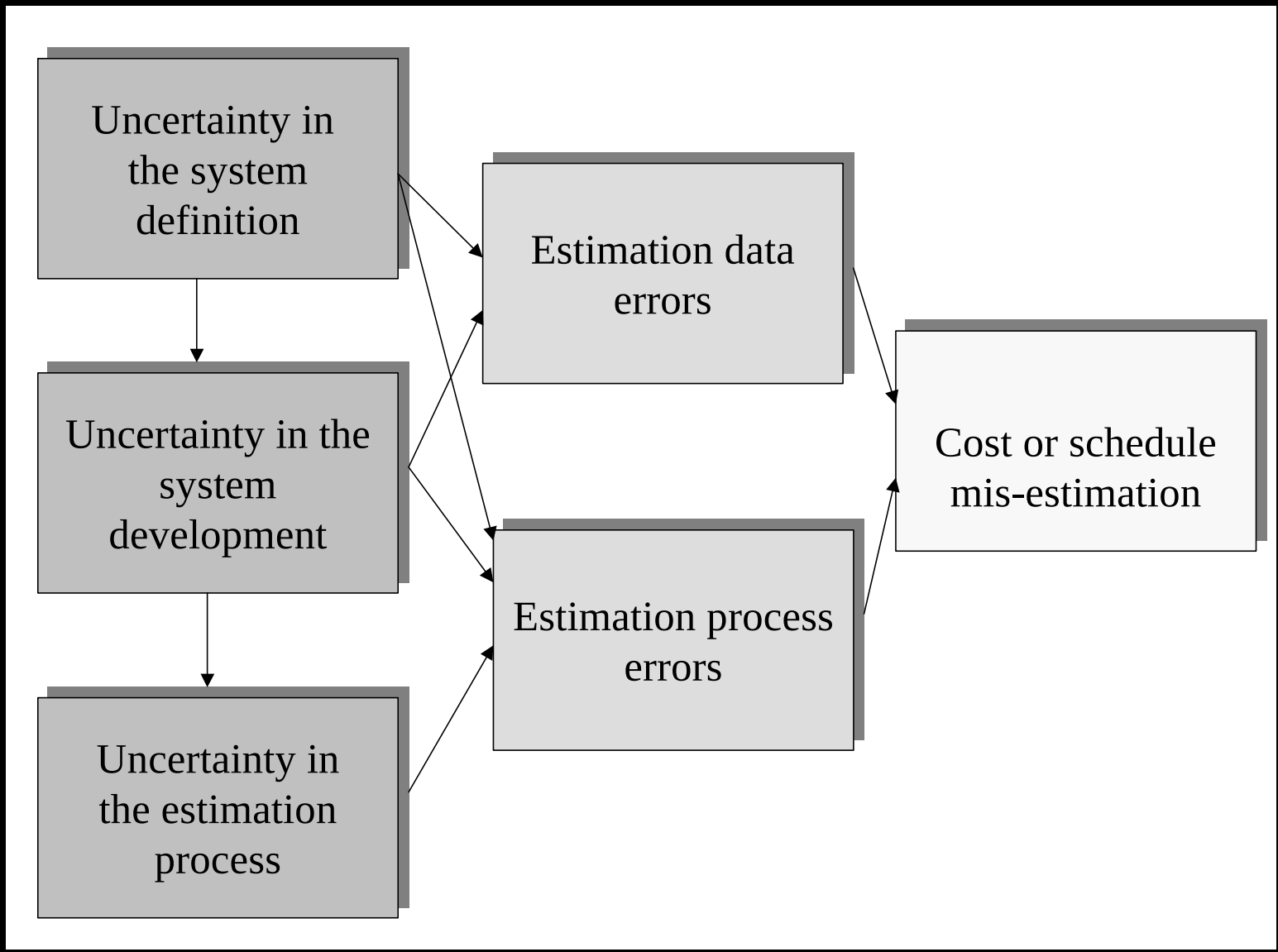
What Causes Errors in Cost Estimation?



What Are the Risks?

- Uncertainty in specification or design
  - Problems in understanding requirements or design
  - Incomplete or inconsistent requirements or design
- Uncertainty about the development method
  - Economies and diseconomies of scale
  - Mismatch between development method and estimation's assumed method
- Uncertainty in the estimation process
  - Subjectivity and lack of independence in estimation factors
  - Counter-intuitive values for estimation factors

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Example 1 from Estimation Checklist

Symptom: There is a lack of evidence that developers are heeding or will adhere to software management plans.

Warning signs include:

- Lack of communication between project managers and developers.
- Developers are unaware of schedules, deadlines or milestones.
- The intent of and conformance to software management plans are not consistently understood or applied across the development organization.
- There is inadequate monitoring, mitigation and reporting of planned milestones compared with actual achievement.

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Example 2 from Estimation Checklist

Symptom: No consideration is made about whether it is cheaper to rebuild a component from scratch or to maintain it.

Warning signs include:

- No trade study analysis exists to demonstrate the decision rationale.

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Reorganized Checklist

- **1. Project/System**
- *Are the system concepts and functions well defined?*
- Action: Review the section on Risks: “Problems in understanding the requirements or design.”
- *Is the system architecture (to include interfaces) complete?*
- Action: Review the section on Risks: “Incomplete or inconsistent requirements or design.”
- *Does the size of the system warrant decomposition and estimation of the elements?*
- Action: Review the section on Risks: “Economies and diseconomies of scale.”

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Next Steps

- **Estimated availability of final report: March 2005**
  - **Citation: *Software Cost Estimation and Sizing Methods, Issues, and Guidelines*, Shari Lawrence Pfleeger, Felicia Wu, Rosalind Lewis, MG-269-AF, ISBN: 0-8330-3713-7**
- **Efforts to build risk assessment into acquisition process, software development process**
- **Efforts to re-estimate during development, tying re-estimates to changes in requirements**
- **Reflect new approaches in *Software Engineering: Theory and Practice*, 3rd Edition, Shari Lawrence Pfleeger and Joanne Atlee, Prentice Hall, 2005.**

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Questions?


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